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(54) System for the assembly of a metal joining-piece and a high-pressure composite material tube - notably applications for equipment used in the oil industry.

(57) Device to permanently link a metal joining-piece and a composite material tube, to a tube subjected to static pressure up to 150 MPa. The assembly consists of a metal part constituting a sealing (8) and joining (7) piece with a collar (2), onto which the composite material (1) is attached. A tubular anti-abrasion and anti-corrosion (6) sleeve, flush-mounted in the metal joining piece and protected by a ring (9) at its end ensures total isolation of the composite/metal joint from corrosive fluids which may be flowing through the tube. In particular, the application of the device to oil industry sensors.

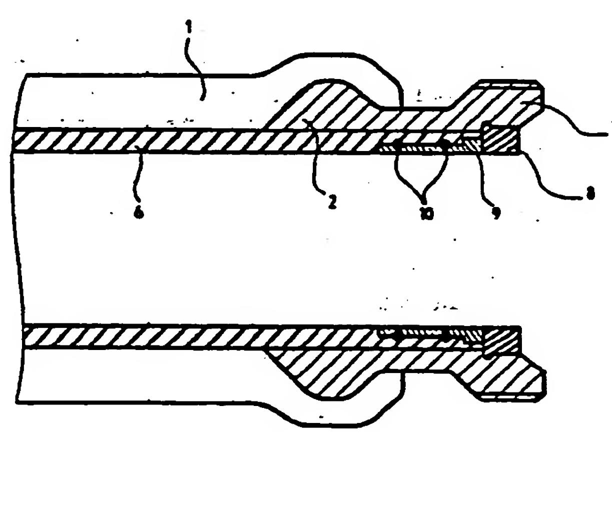

fig-2

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SYSTEM FOR THE ASSEMBLY OF A METAL JOINING-PIECE AND A HIGH-PRESSURE COMPOSITE MATERIAL TUBE -NOTABLY APPLICATIONS FOR EQUIPMENT USED IN THE OIL INDUSTRY

This invention concerns an assembly system for composite material and metal, making the use of composite materials for transportation of corrosive and/or abrasive fluids possible at static pressures of up to 150 MPa.

In particular, the invention facilitates insertion between metal tubes (through which a fluid under very high pressure is flowing) of a composite tube element which may be part of a sensor designed to measure various properties of the fluid (viscosity, flow-rate, density, etc.)

One of the problems recognised in the previous state of the art was the difficulty of realising composite material/metal joints able to withstand very high pressures for long periods of time. The invention solves this problem.

One most important application is to sensors used in oil and oil-related industry, used, as is well-known, to measure the properties (viscosity, density, rheology, etc.) of fluids piped under very high pressure, which may be corrosive (acids) and/or highly abrasive (cement slurries).

Using the invention, a metal joining-piece with a projecting collar at the end in contact with the composite material and a high pressure joining element at the other end is placed between the composite material and the metal tube.

Figures 1 and 2 show a non-limitative, preferred method for realisation of the joint in longitudinal section of depicting a plane parallel to the tube axis.

One of the invention's essential characteristics is the projecting collar (2) around which the various layers of composite material are placed in the accustomed manner, by winding.

The advantage of this structure is that normal winding of the composite material is made possible while, for the first time, resistance to tensile and torsional stresses occurring between the metal tube (and the metal joining-piece) on the one hand, and the composite tube on the other, is ensured.

Thus, risk of distortion, leaks and fractures, which are common in attempts made in the previous state of the art, is eliminated.

Considering the working pressures, it is evident that this advantage is quite decisive.

Within oil and oil-related industry, the drawbacks of the previous state of the art have even more serious consequences (any interruption of work on a line involves serious risks : bad well treatment, bad cement placement ; with sometimes unsalvagable consequences).

References are as follows :

1 . Wound composite material

2 . Collar on metal joining-piece

3 . Metal joining-piece

4 . Circumferential fibres of the composite material

5 . Longitudinal fibres of the composite material

P . Pressure exerted by the pump fluid inside the tube

S . Tube section

F . Forces of longitudinal tension due to pressure

R . Radius of collar

AB . Angles of the oblique planes of the collar

6 . Anti-abrasion/anti-corrosion sleeve

7 . "Weco" type assembly system with a high-pressure metal tube not shown

8 . High-pressure seal

9 . Protective ring

10. O-rings

Figure 3 is a drawing of a sensor (11) mounted on the tube. The sensor measures the properties of the fluid travelling through the tube, taking measurements through the tube's (1) composite material walls.

Figure 4 shows the working principle of the invention in detail.

When a very high pressure P is applied inside the tube, it creates a strong tensile force $F = PxS$ within the material constituting the tube.

The longitudinal fibres (5) of the composite material partially absorb this force. In the joint zone of the composite tube and the metal joining-piece (3), shearing forces at the interface of the two materials reach values such that no adhesive suffices to keep the assembly together.

It is in this context that the assemblies of the previous state of the art are fragile. Using the invention discussed here, the composite material tube is wound around projecting collar (2) on the metal joining-piece.

When a pulling force is exerted on the tube, any slippage should be absorbed by the increase in diameter of some of the turns in the layer of circumferential fibres (4) in the composite material.

These fibres consist of a material with very high Young's modulus, as is notably the case in glass, carbon or aramid fibres. It is therefore very difficult, if not impossible, to cause the assembly to slip, whether by pulling apart or by compressing. This is due to the shape of the collar (2) which has two oblique planes with angles A and B.

To avoid breaking the longitudinal fibres by incipient fracture, care will be taken to select appropriate radii R for the collar.

Collar profile may be chosen in various ways, but it should preferably have a shape which causes diameter changes to be as "gentle" as possible.

In another preferred method of winding, composite material fibres are wound in two symmetrical spirals (one left-handed, the other right-handed), with the fibre angle, measured in relation to the tube axis, being from 50 to 60. It is well-known that a tube consisting of spirally wound fibres wound at an angle of approximately Arc tan (2), 54.73 , is practically unexpandable through the effect of pressure forces.

Finally, it is possible to envisage the configuration of the invention as a combination of more than 2 layers of fibres with winding angles selected from the examples given.

Figure 2 is a drawing of the invention. A sleeve 6, made of a material (notably polyurethane or polytetrafluorethylene) which is resistant to (corrosive or abrasive) fluids pumped, protects the composite material form chemical attack. In fact, it is known that resins linking the material's reinforcing fibres can be dissolved by certain fluids and that glass fibres are attacked by hydrofluoric acid.

The sleeve 6 can be used advantageously when manufacturing the tube. It can be used as a guide when winding the composite material over the metal joining-piece 2.

The metal part 9 attached to the seal 8 enables the end of the sleeve 6 to be protected against abrasion. The O-rings 10 provide a complete seal, so preventing penetration of aggressive fluids between part 9 and the sleeve 6, through the effect of pressure.

In this example, the end 7 of a "Weco" type female high-pressure joint has been depicted. The WECO assembly system is well-known, especially in oil and oil-related industry. It could, however, be replaced by any other system, known to those skilled in the art, which would be capable of resisting the very high pressures mentioned here.

Figure 3 shows the application of the invention to the implementation of Sensors which can be attached to high-pressure lines. In this application mode, the sensor (11) measures one or more properties of the fluid travelling through the composite tube 1. The Sensor may be a flow meter, densitometer or conductivity measuring sensor of known type not requiring detailed description here.

Finally, figure 4 shows a very high pressure pipe with a male and female (respectively) "Weco" type joint at each end, joined to the composite material tube using the invention.

The interest of using polymer-based composite materials for high-pressure lines lies above all in the great weight-saving, which makes for easier handling and the possibility of carrying a larger number of pipes per lorry. For industry, notably oil and oil-related industry, this advantage is of utmost importance, especially in the oilfield and offshore.

One particularly interesting application is the non-intrusive measurement of the density of a fluid travelling through a tube. One frequently-used technique consists of measuring the absorption, by the said fluid, of photon radiation emitted by a source placed diametrically opposite the detector. Radiation absorption is related to the fluid density by an exponential law. After the device has been calibrated, the signal picked up the detector can be converted directly into density.

Use of this technique in the industrial and oil-industry context, particularly when high pressures are being used, requires that the device be installed on relatively thick tubes, generally of metal, which results in much of the radiation emitted form the source being absorbed by the tube ; considering this additional absorption, the radiation level imposed by detector sensitivity requires the use of highly active photon sources. This considerably complicates on the one hand the legislation and administrative channels required when using radioactive sources and, on the other, makes use of heavy and bulky protective shielding necessary. The invention discussed here uses a tube of composite material as part of the standard density measurement device. This material has the property of absorbing considerably less of the radiation in question than steels and, more generally, metals, which makes it possible to considerably reduce the radiation source activity while retaining an identical detection. Consequently, protective shielding round the source and so the weight and size of the assembly are also reduced. Moreover, composite materials have mechanical and chemical properties which are comparable with or superior to those of metals, so making use of this technique possible in a large number of industrial applications and hostile environments. The above-mentioned properties of composite materials have been known for around ten years. However, it has not, in that time, seemed possible to use them within the field of very high pressure devices using a permanent radiation source. Also, the industry did not have any reliable means of making metal/composite joints capable of resisting these very high pressures. This includes oil field applications. Experiment has shown that, in fact, use of these materials is compatible with the application envisaged, particularly as a result of the assemblies described above.

Figure 5 shows a section, in a plane perpendicular to the tube, through an experimental gamma ray device.

Figure 6 shows the longitudinal section of the same device.

The same numerical references designate the same elements in both these figures.

Element 1 is the composite material tube ; it is complete, i.e. must not be machined, in order to respect standards concerning the use of high pressures. Its diameter, length and wall thickness are defined depending on the circumstances in which the densimeter is used. The fluid 7 the density of which is to be measured, flows through the tube. Depending on the individual application, and especially depending on the fluid pump, a protective covering 10 inside the tube may be required, particularly if the fluid is an acid. The covering should be of a material of the polyurethane or polytetrafluorethylene type, or analogous, in order to conserve good anti-abrasion properties, particularly in applications using cement slurries. Element 8 is the photon source support, the source in this case being of the chemical radioactive type. This element is made of lead contained in a support which mechanically solid and well attached to the shielding 2 which encircles the tube 1. The lead is present to absorb the radiation emitted by the source 3 in directions other than those defined by the collimator window 6, thus limiting doses of escaping radiation around the device to the values defined by radioprotection standards. In this case, the source 3 is a radioisotope the nature and activity of which are defined as a function of the densimeter operating conditions (tube dimensions, detector type, type of fluid flowing through the tube). Depending of requirements, a source obscuring system may be considered. Element 2 is the shielding encircling the composite tube. The shielding consists of a substance which greatly absorbs high energy photons (100 to 1000 KeV), such as steel, lead, tungsten, tantalum or a combination of these materials. It is designed to attenuate those photons which, after interacting with an atom in the fluid or tube, are diffused in directions other than their original direction.

The thickness of the shielding depends on the material of which it consists, source activity and device dimensions, and should be defined taking the standards defined by radioprotection bodies into account. A shield, shown at number 9 and consisting of the same materials or a combination of them, also surrounds the detector 4. The two elements 2 and 9 can be either all in one part or two individual parts mechanically joined (e.g. by welding) to form one non-separable assembly. Element 9 is also a support for the detector 4. Element 4, which is not shown, is a standard radiation detector of the ionising (ionising chamber, proportional counter, Geiger-Mueller counter), scintillation or semiconductor type. Choice of detector depends on the circumstances in which the densimeter is used. The detector includes the electronic circuitry required for operation. Elements 6 and 5 are, respectively, the collimator windows for source an detector. Source collimation 6 is defined by an aperture in the support 8 and the shield cylinder 2. Geometry is adapted to the various densimeter element dimensions and depends on the desired degree of collimation. On the detector side, the collimator window 5 also consists of a rectangular aperture in the shield cylinder 2 ; width, shown in figure 5 and length, shown in figure 6, of this window depend on the radiation beam angle defined by source collimation 6, detector size and tube dimensions. The angular limits of the "exploitable" photon beam emitted by the source are shown in figures 5 and 6, as is the possible course of some photons (symbolised by waved arrows) in the various cases envisaged.

The principles of operation of this device are identical to those of existing radiation densimeter. The photons emitted by source 3 and collimated through window 6 firstly cross the first composite tube wall, then the fluid flowing through the tube and finally the second tube wall, before entering the detector assembly.

During this course, each photon has a certain probability of undergoing one or more interactions with the atoms in the material it is passing through ; this probability is all the higher, the greater the density of the material considered. The result of these interactions is either absorption of the photon by an atom in the material (i.e. its disappearance) [photoelectric effect], or re-emission of the photon, which then has an energy value slightly less than its initial one and travels in a different direction from the original one [Compton diffusion]. The principle of densimeter measurement relies on detection of those photons which pass between the source and the detector without interacting on the way. It is obvious that the number of photons which do this varies in inverse proportion to the density of the materials crossed and also with the distance travelled through each material. The materials crossed in the case of a radiation-based densimeter are the tube and the fluid the density measurement of which is required. It can therefore be understood why it is essential to reduce the effect of tube wall photon absorption. This is the aspect which is the major advantage of the invention. As a result of this use of composite material for the tube, radiation densimeters with considerably reduced source activity, which retain similar or superior performance to standard densimeters, can be used. This is because composite material density

is 4 times less than the density of steel, while composite has mechanical properties comparable or superior to those of steel at wall thicknesses increased by a factor of 2 compared with classical steel tubes. Amongst the advantages of the invention compared with a classical system, over an above that of reducing source activity, the following points should be mentioned :

-total device weight is reduced,

-as composite is more abrasion-resistant than steel, it is perfectly suited to the use of fluids as abrasive as cement slurries or fluids carrying propping agents (sand, stone chips, etc.),

-corrosion and rust problems encountered in steel tubes are eliminated, which, apart from better service life results, also yields the advantage of better quality control and better wall thickness invariability, thus a more stable geometry, which is an important point when seeking high precision of measurements.

Of course, application of the invention is not limited to the oil industry, and covers other known fields in which radiation densimeters, as well as other sensors such as flow meters, etc., are used. The invention is sure to be of great usefulness in all fields in which a tubular element (sensor, etc.) is applied to a tubular metal line, and where the composite material construction of the tubular element affords great advantage (the choice of composite material having previously been impossible due to the absence of suitable metal/composite joints, especially in high pressure applications).

Claims

1 - System for the assembly of a composite material cylindrically symmetrical part and a metal part, capable of resisting very high internal pressures (150 MPa), characterised in that the end (1) of the composite material part at least partially encloses and covers a cylindrical-symmetrical metal joining-piece (3) featuring a collar (2) of the same internal diameter at one end, the section of which has a more or less trapezoidal shape (2) in the plane of the axis of symmetry, around which the reinforcing fibres of the composite material are "wound" ; it is also characterised in that the other end of the metal joining-piece (3) consists of a high pressure joint (7) to be attached to the part to be joined.

2 - System in accordance with claim 1, characterised in that the composite material part and the metal joining-piece are capable of resisting very high pressures, and in that the metal part to be attached is either a very high pressure tube or a very high pressure plug.

3 - System in accordance with claim 1 or 2, characterised in that the composite material in the area of metal interface with the metal joining-piece (3) consists of at least one longitudinal layer (5) of reinforcing fibres, lying in a direction parallel to the axis and at least one circumferential layer (4) of reinforcing fibres, wound in more or less circular turns placed in directions more or less perpendicular to the system's axis of symmetry.

4 - System in accordance with claims 1 to 3, characterised in that the inside wall of the composite material tube is fitted with a tube (6) which protects the composite material from any agressive fluids which may be pumped through the tube, particularly acids and abrasive fluids.

5 - System in accordance with claim 4, characterised in that the protective tube is of a polyurethane, polytetrafluorethylene or analogous material.

6 - System in accordance with claims 1 to 5, characterised in that the composite material consists of a fibre-linking resin and of reinforcing fibres which may be glass, carbon, aramid, or analogous fibres.

7 - Sensors, notably for use in oil and oil-related industry, consisting of a very highly pressure-resistant composite material tube through which a fluid travels, certain properties of which are measured by the sensor, characterised in that the composite tube has, at at least one and perferably at two ends, an assembly system in accordance with claims 1 to 3.

8 - High pressure composite material tubes which can be joined together to form a variable length line, and which are compatible with very high internal static pressures (150 MPa), characterised in that each composite tube has, at both its ends, an assembly system in accordance with claims 1 to 3, male/male, female/female or, preferably, male/female.

9 - High pressure composite material tube, jointable in accordance with claim 8, characterised in that the inside of the composite tube has a protective tube in accordance with claim 4 or 5.

10 - Densimeter comprising an energetic photon source (3) [100-1000 KeV] and a detector (4) which measures photon absorption by the fluid flowing through a tube characterised in that said tube consists of a material made of synthetic fibres linked together by a polymer resin [material said to be "composite"] (1), the fibres preferably being of one of the following types : glass, carbon or aramid, the entirety being enclosed, in the area of photon diffusion, by a metal cylinder which greatly absorbs the photons emitted by the source and has a window (6) for the source and a window (5) for the detector (4).

11 - Densimeter in accordance with claim 1, characterised in that the source (3) emits, by radioactivity, gamma photons, and preferably has an activity of less than or equal to 25 mCi, and in that the detector (4) is of one of the following types : ionisation, scintillation or semiconductor, or in that the source (3) emits X-ray photons by means of an artificial device of the X-ray tube or X-ray laser type and in that the detector (4) is of one of the following types : ionisation, scintillation or semiconductor.

12 - Densimeter in accordance with any one of claims 1 to 5, characterised in that the internal wall of the composite tube is clad with a protective anti-acid material 10 of one of the following types : polyurethane, polytetrafluorethylene or an analogous product, and in that the material constituting the shield cylinder (2) is of one of the following types :
steel, lead, tungsten, tantalum or a combination of these materials.

13 - Densimeter in accordance with any one of claims 10 to 12, characterised in that it has, at at least one of the tube ends, and preferably at both, an assembly in accordance with any one of claims 1 to 6.

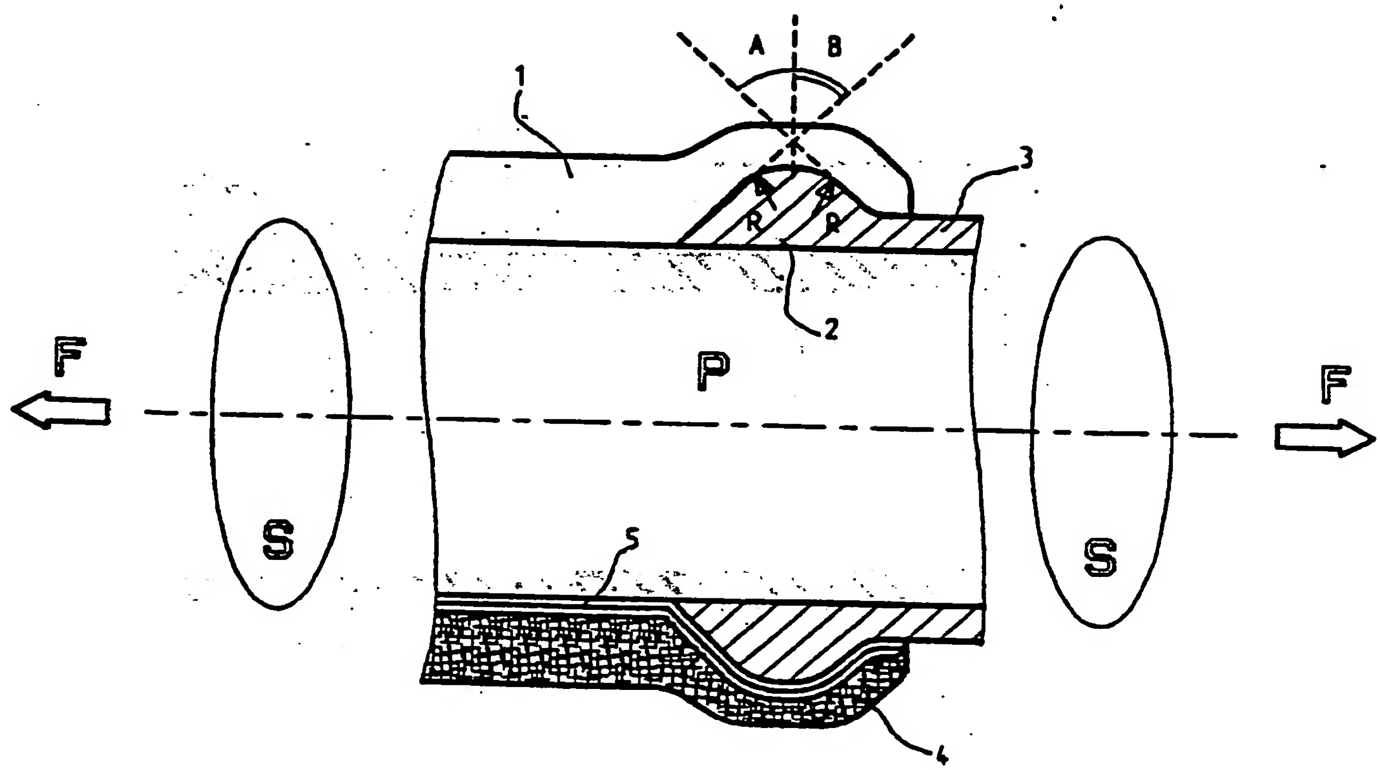

fig-1

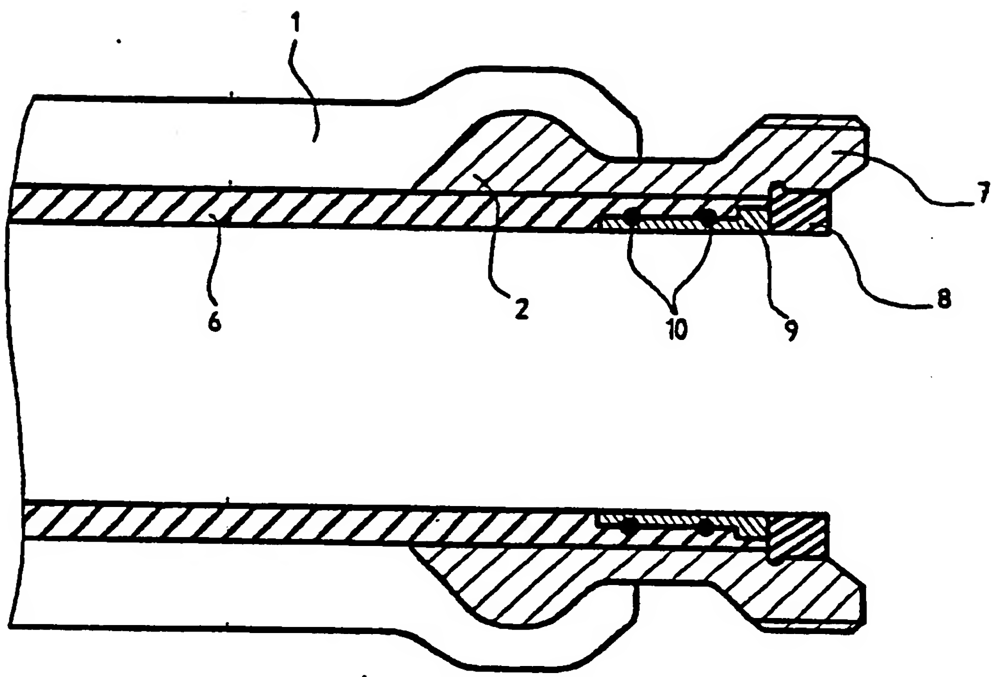

fig-2

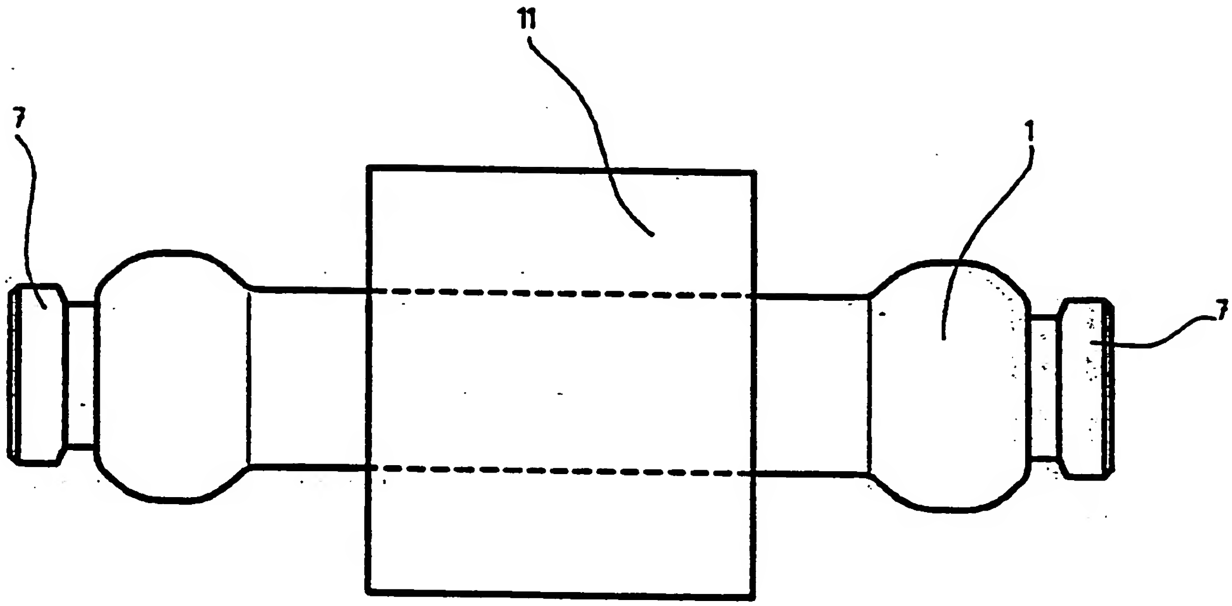

fig-3

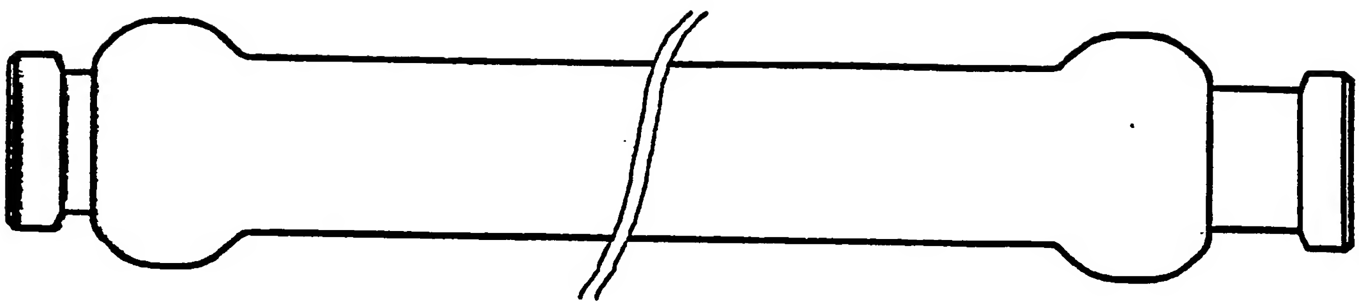

fig-4

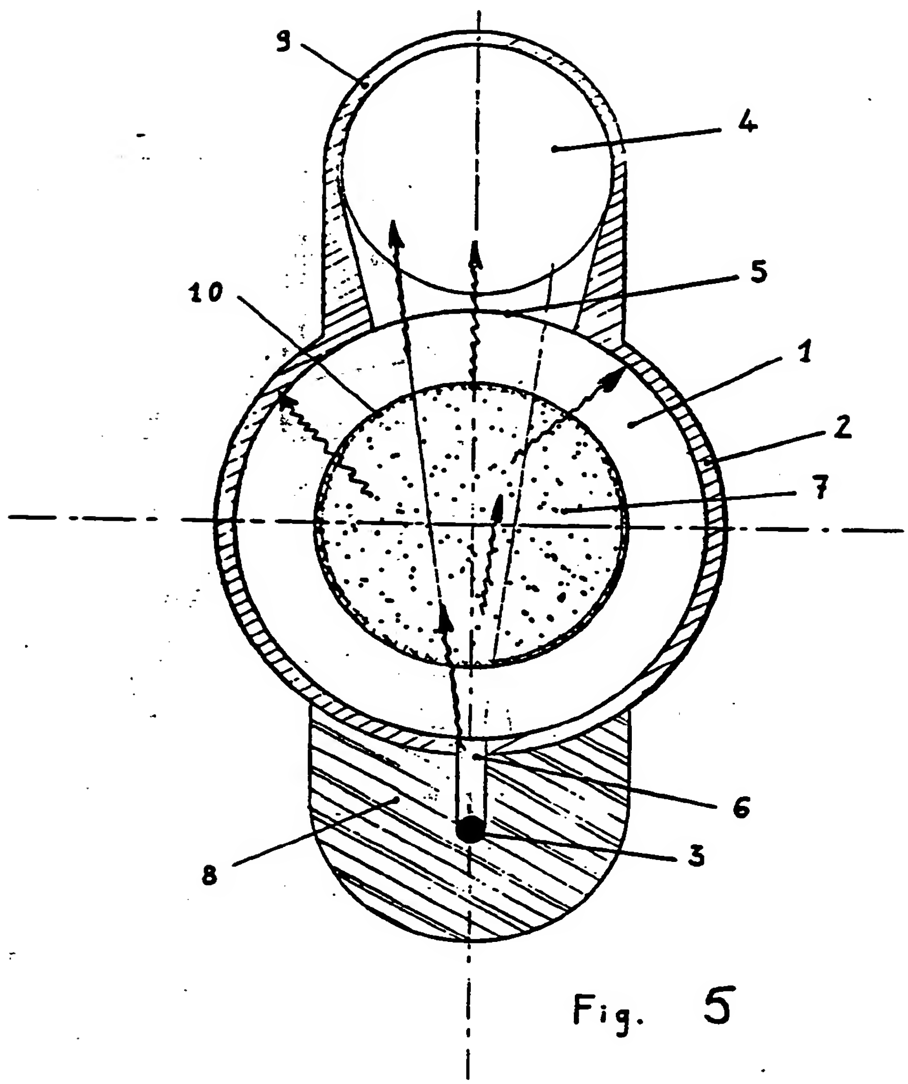

Fig. 5

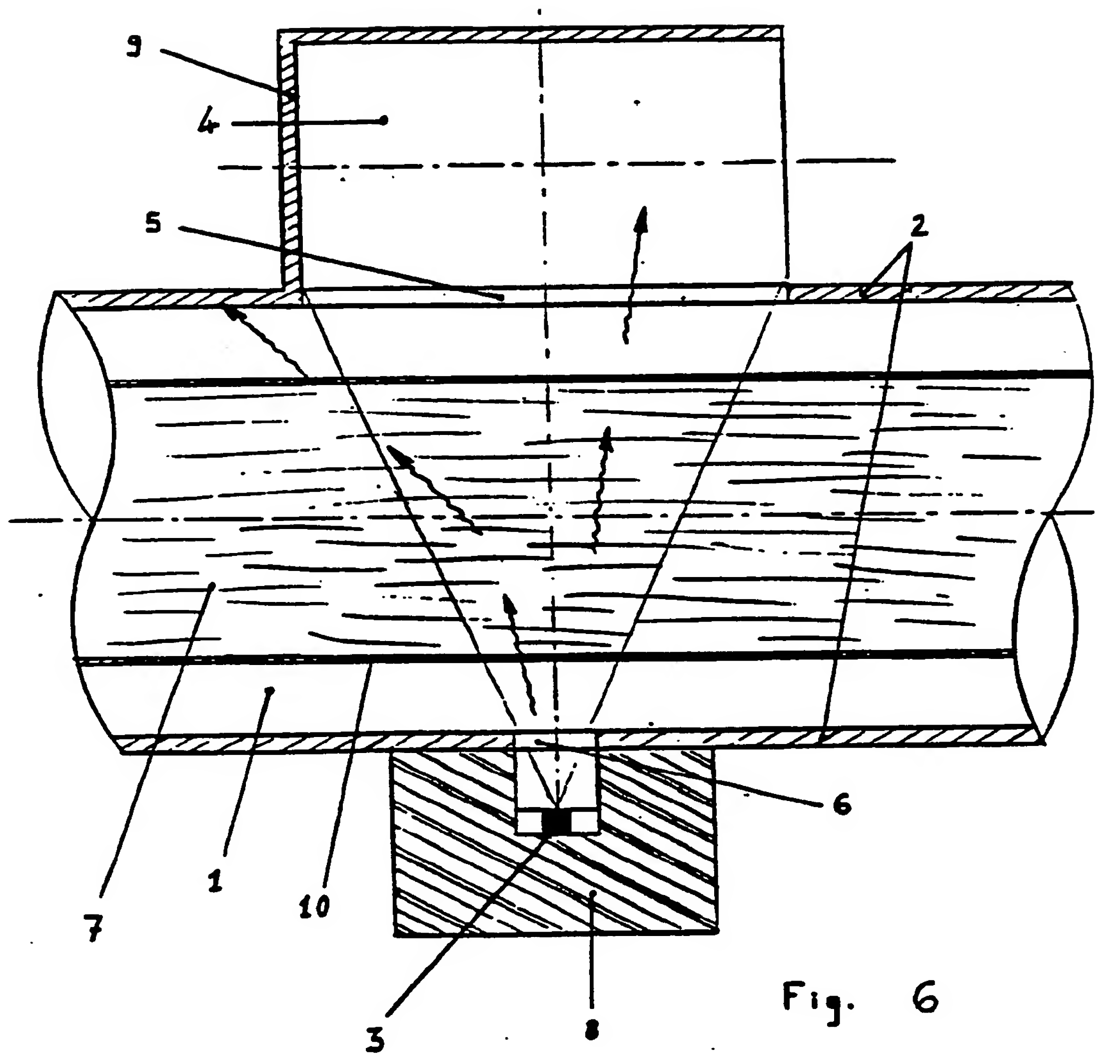

Fig. 6

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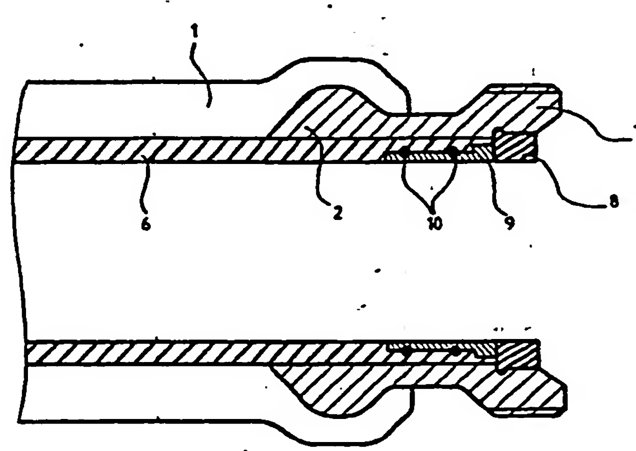

fig-2

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European Patent Office

EUROPEAN SEARCH REPORT

Application number

EP 87 201 852.8

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 4)
X	US - A - 2 219 047 (A.D. MACLACH-LAN) * page 1, left-hand column, lines 1-13; left-hand column, line 52 - right-hand column, line 20; right-hand column, line 51 - page 2, left-hand column, line 2; claim 1; figure 1 * --	1,2	F 16 L 33/00 G 01 N 9/24 G 01 N 21/05 G 01 N 21/53 G 01 N 23/12
A	--	3,4,8	
X	US - A - 2 854 030 (SCHULTHESS) * column 1, lines 1-40; claims 1, 2; figures 1,2 * --	1,2	
A	--	3-5,8	TECHNICAL FIELDS SEARCHED (Int. Cl. 4)
A	GB - A - 2 009 875 (BRIDGESTONE) * figures 1,2, * --	1,2	F 16 L 31/00 F 16 L 33/00 F 16 L 47/00 E 21 B 17/00 G 01 N 23/00
A	DE - U - 1 932 448 (H. KLEIN) * page 2, lines 5-15,27 - page 3, line 13; claim 1; figures * --	1-4,6	
A	AT - B - 320 362 (SCHWARZ) * page 2, lines 1-18; page 3, lines 24-46; figures 1-5 * --	1,6	
A	US - A - 4 313 629 (WINTERHALTER) * figures 4,6 * --	1,2	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Berlin	20-06-1988	C. SCHAEFFLER

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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CLAIMS INCURRING FEES

The present European patent application comprised at the time of filing more than ten claims.

- [ ] All claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for all claims.
- [ ] Only part of the claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims and for those claims for which claims fees have been paid.

  namely claims:
- [ ] No claims fees have been paid within the prescribed time limit. The present European search report has been drawn up for the first ten claims.

LACK OF UNITY OF INVENTION

The Search Division considers that the present European patent application does not comply with the requirement of unity of invention and relates to several inventions or groups of inventions.

namely:

1. Claims: 1-9 System for the assembly of a composite material part and a metal

2. Claims: 10-13 Densimeter comprising an energetic photon source and a detector

- [x] All further search fees have been paid within the fixed time limit. The present European search report has been drawn up for all claims.
- [ ] Only part of the further search fees have been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the inventions in respect of which search fees have been paid,

  namely claims:
- [ ] None of the further search fees has been paid within the fixed time limit. The present European search report has been drawn up for those parts of the European patent application which relate to the invention first mentioned in the claims,

  namely claims:

European Patent Office

EUROPEAN SEARCH REPORT

Application number
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- page 2 -

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.4)
A	EP - A - 0 132 067 (HALLIBURTON) * page 4, lines 1-25; figures 1,5 * --	10,11	
A	US - A - 4 180 735 (SIPILÄ et al.) * abstract; figure 1 * --	10,11	
A	INTERNATIONAL JOURNAL OF APPLIED RADIATION AND ISOTOPES, vol. 34, no. 1, January 1983, pages 309-331, Oxford, GB; J.S. WATT: "On-stream analysis of metalliferous ore slurries" * page 327; figure 21 * --	10-12	TECHNICAL FIELDS SEARCHED (Int. Cl.4)
A	US - A - 3 551 672 (HOMER III et al) --		
A	GB - A - 2 059 581 (AUSTRALIAN ATOMIC ENERGY) --		
A	DE - A - 2 064 504 (L. KROHNE) ----		

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